Results from a Wetlands GNSS-R Aircraft Campaign

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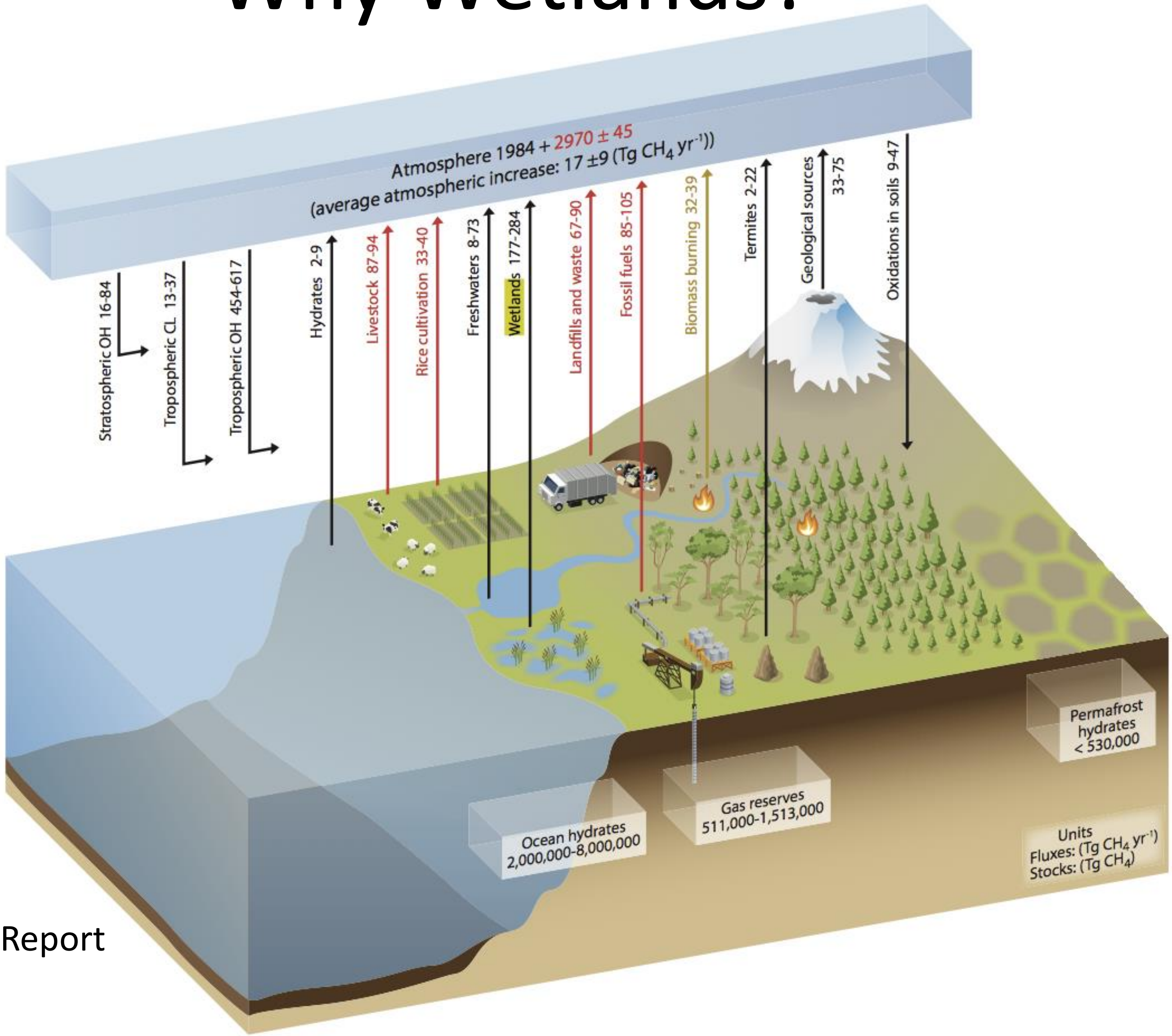
Outline

- Why Wetlands?
- Flight Campaigns
- Preliminary Results
- Future Work

Why Wetlands?



IPCC AR5 Report

Why Wetlands?

- Wetlands largest contributor of atmospheric methane
  - Wetland contribution has largest uncertainty
- On century timescales, atmospheric methane ~25X more potent than CO_2 as a greenhouse gas
- Wetlands are important:
  - Link to climate change through CH_4 production
  - Mitigate storm damage / flooding
  - Groundwater recharge
  - Terrestrial water storage
  - Sea-level rise
  - Biodiversity
  - Species extinction
- Highly sensitive to climate change
  - Feedback

Why GNSS-R?

- Urgent need to monitor wetlands and their dynamics
  - Current backscatter instruments have attenuation issues
  - Mapping yearly global wetland extent is problematic

- Advantages of GNSS-R for wetland observations:
  - Bistatic geometry: Forward scattering is dominant for flat conducting surfaces
  - High spatial/temporal sampling
  - L-band may penetrate overlying vegetation

- Can bistatic L-band GNSS signals penetrate vegetation to map inundation extent?

  => Aircraft test

Wetland Flight Experiments

Primary Objectives

- Quantify GNSS signal penetration as function of vegetation
  - Ground truth: small scale surface features, low velocity
- Study how polarization can improve science
- Verify models for coherent and incoherent scattering
  - Terrain roughness spectrum
  - Vegetation
  - Code-limited vs Fresnel-limited signals

Secondary Objectives

- Assess higher chipping rate public signals (GPS L5)
- Demonstrate codeless processing of encrypted signals (GPS M1/2)

Wetland Flight Experiments

- Limited funding, small equipment package => Cessna
  - Took from Dec 2014 to Dec 2016 to get flight clearance from Armstrong Flight Research Center

- Three flight days:
  1. Dec 13, 2016: Equipment checkout: Lakes
     - Lakes represent inundation with no-vegetation

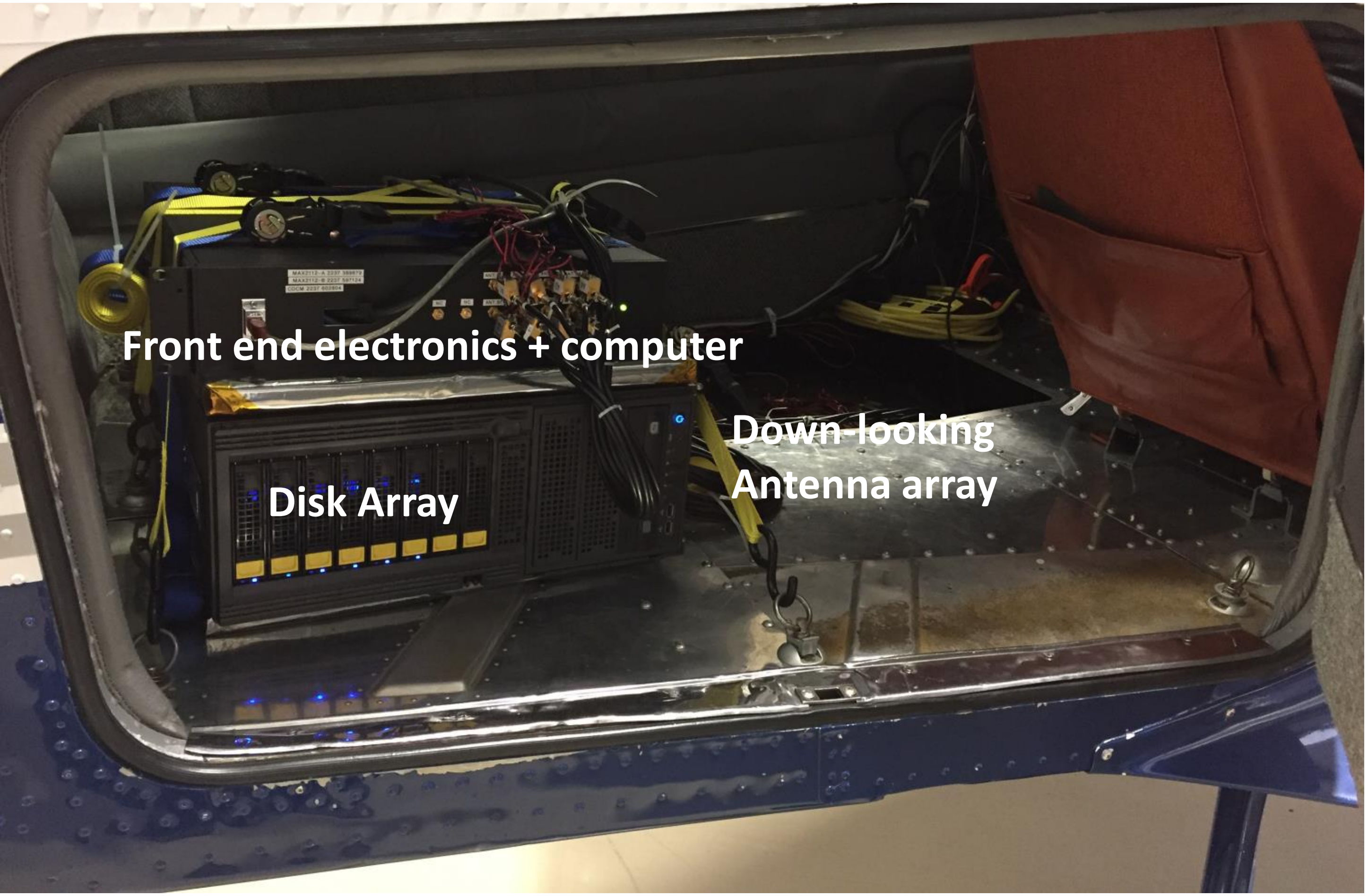
  2. Jan 25, 2017: California wetlands / Ramsar sites
     - Large number of wetland sites from Seal Beach CA to Chico CA

  3. May 1-3, 2017: Caddo Lake TX/LA
     - Very dense vegetation
     - Ultimate test for GNSS-R penetration

Wetland Flight Experiments

Cessna 310. Refueling stop in Deming NM

Wetland Flight Experiments

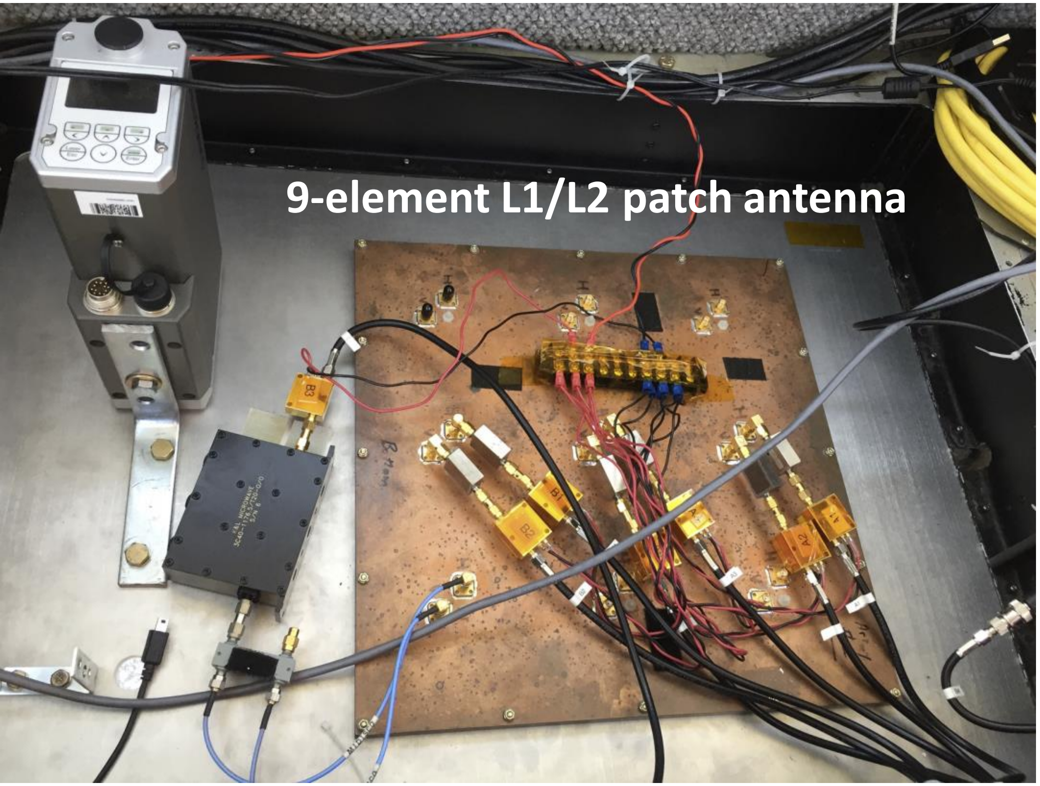


Equipment Package

8 Antenna Inputs, 2 Frequencies each

- 20/40 MHz I/Q sampling

Wetland Flight Experiments



Up-Looking POD antenna:

- L1 + L2 RCP

3 Patch Elements (each):

- L1 + L2 H
- L1 + L2 V

1 Patch Element:

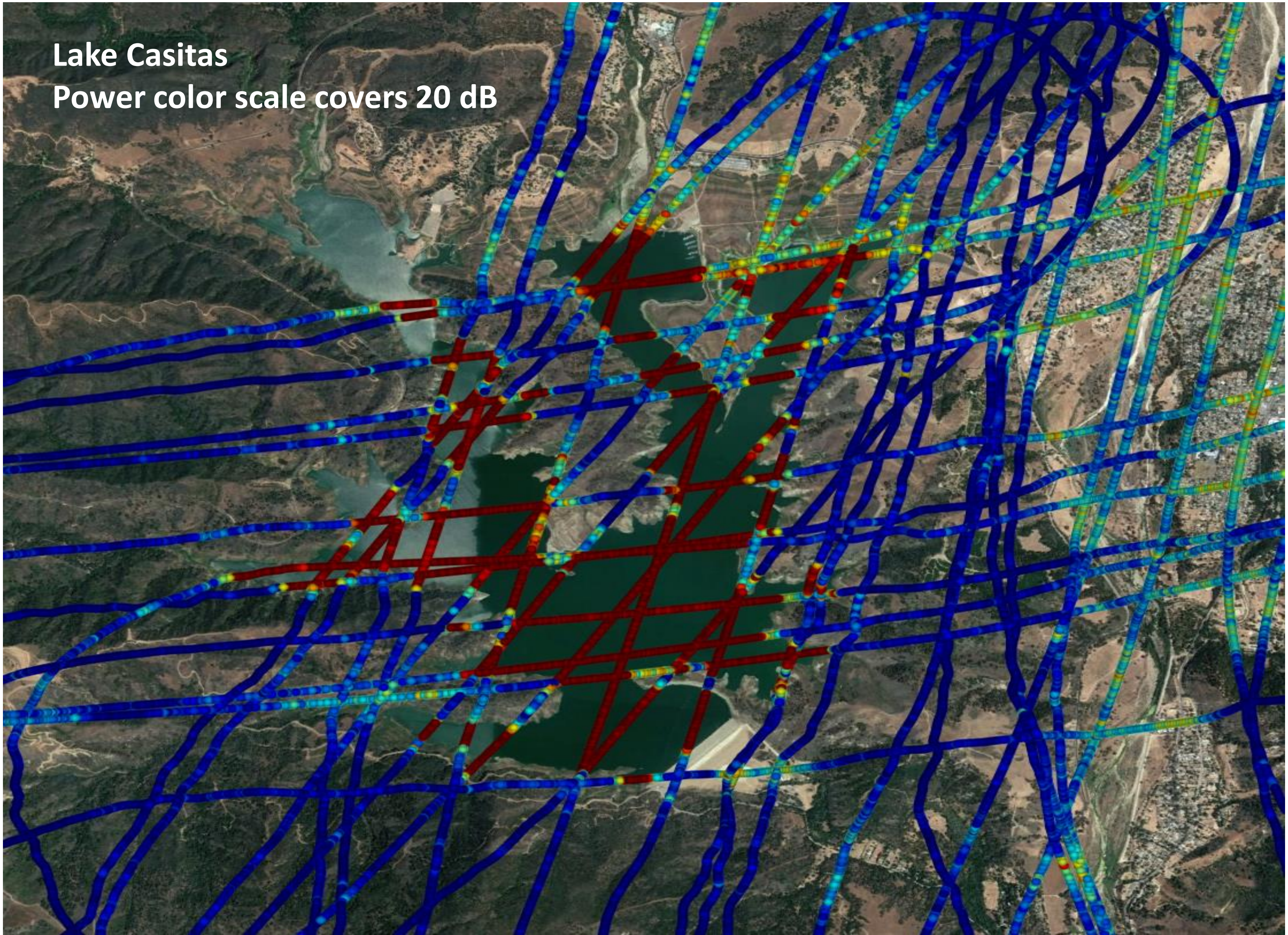
- L1 + L5 LCP

Optical Camera

First Flight

- Santa Clara River
- Castaic Lake (3)
- Lake Piru
- Lake Casitas (4)
- Matilija Lake (2)
- Piru Creek into Santa Clara River

Preliminary Results



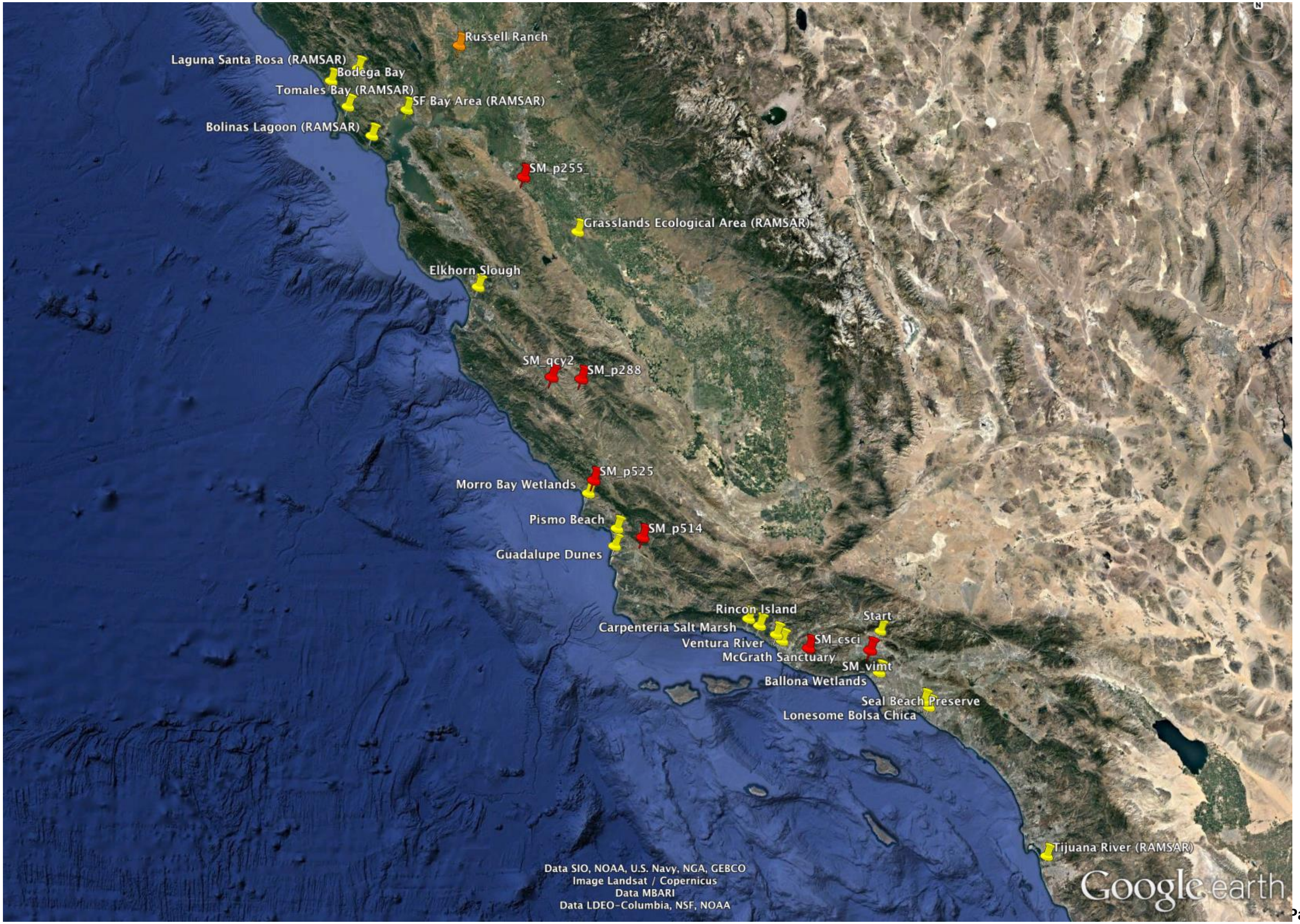
Second Flight

Second Flight

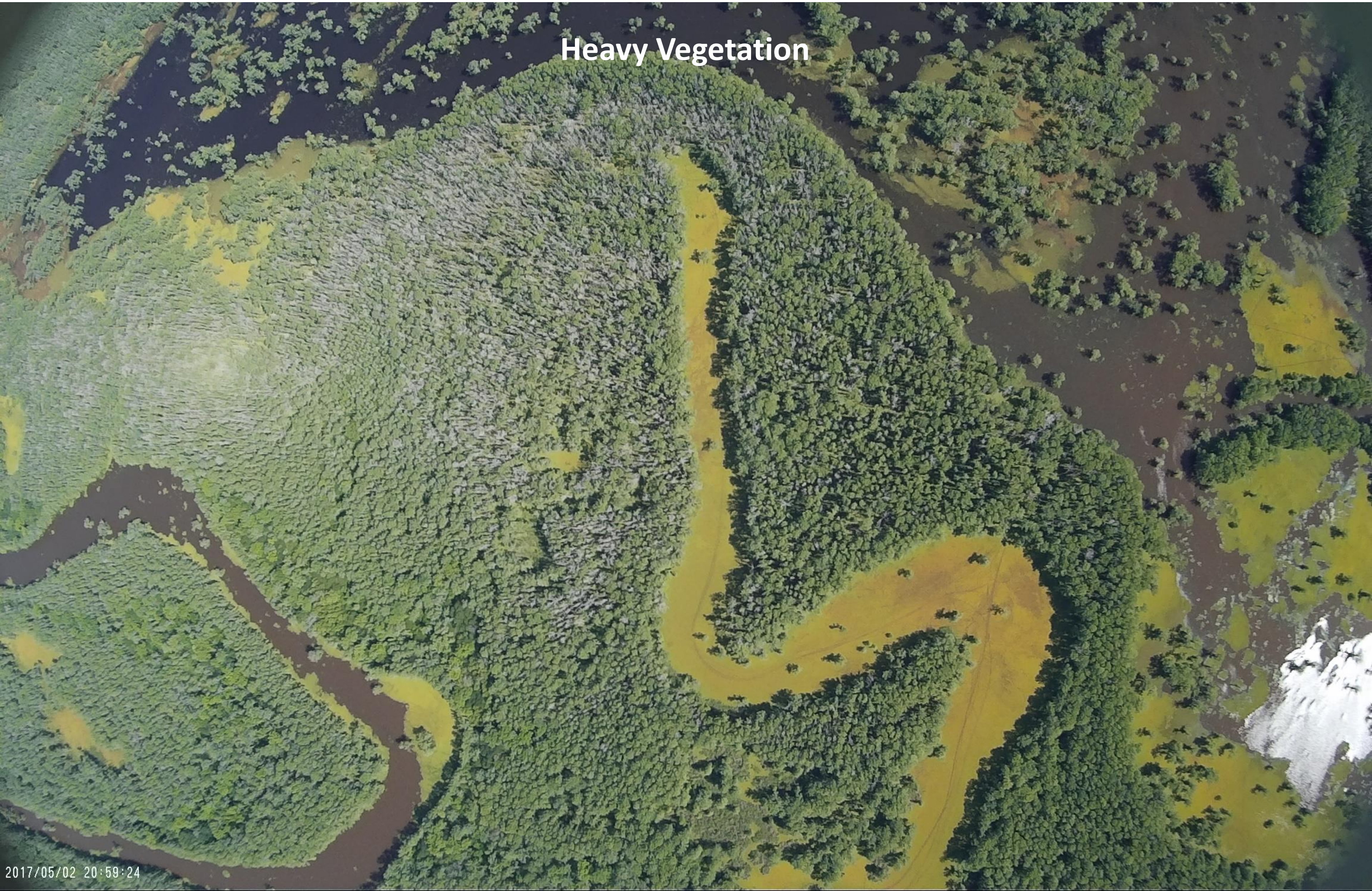
- Number of wetlands / wetland-like regions →
- Several Soil moisture monitoring stations
- Russel Ranch
  - UC Davis Sustainable Agriculture Facility

Carpenteria Salt Marsh
Andree Clark Bird Refuge
Ocedano Dunes National Preserve
Morro Bay Wetlands
Salinas River National Wildlife Refuge
Elkhorn Slough National Estuary
Moss Landing State Wildlife Area
Ellicott Slough National Wildlife Refuge
Eden Landing Ecological Reserve
Don Edwards SF Bay National Wildlife Refuge
Waterbird Regional Preserve
Point Edith Wildlife Area
Prospect Slough
Cache Creek Conservancy
Vina Vernal Pools
Tomales Bay
Bodega Bay
Salmon Creek
Abbotts Lagoon
Drakes Bay
Bolinas Lagoon
Los Banos Grasslands
Soda Lake
Santa Clara Estuary Natural Preserve
Point Mugu Wetlands
Bollona Wetlands
Seal Beach National Wildlife Refuge

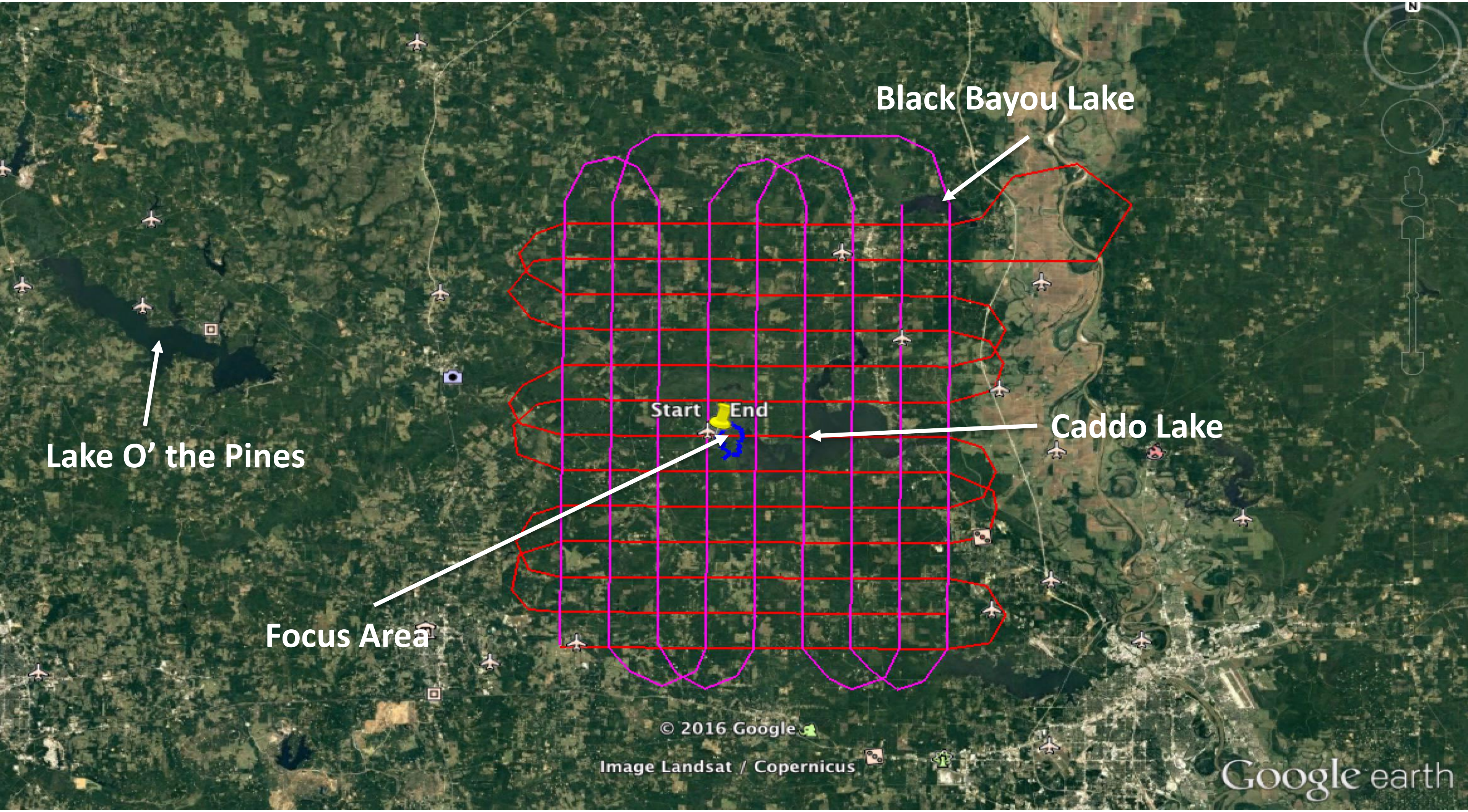
Second Flight



Caddo Lake Flights



Caddo Lake Flights



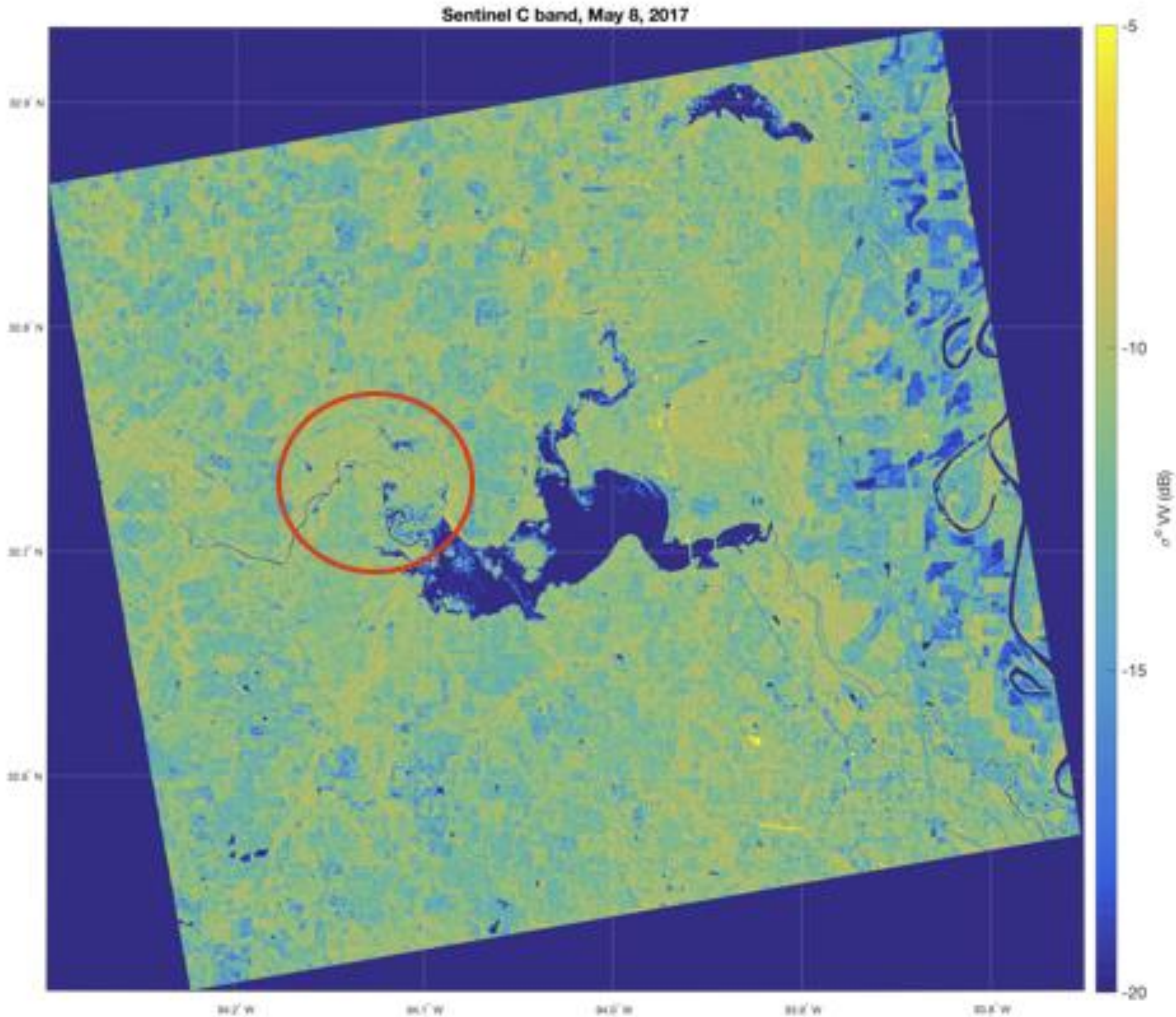
Caddo Lake Flights

Ground Truth

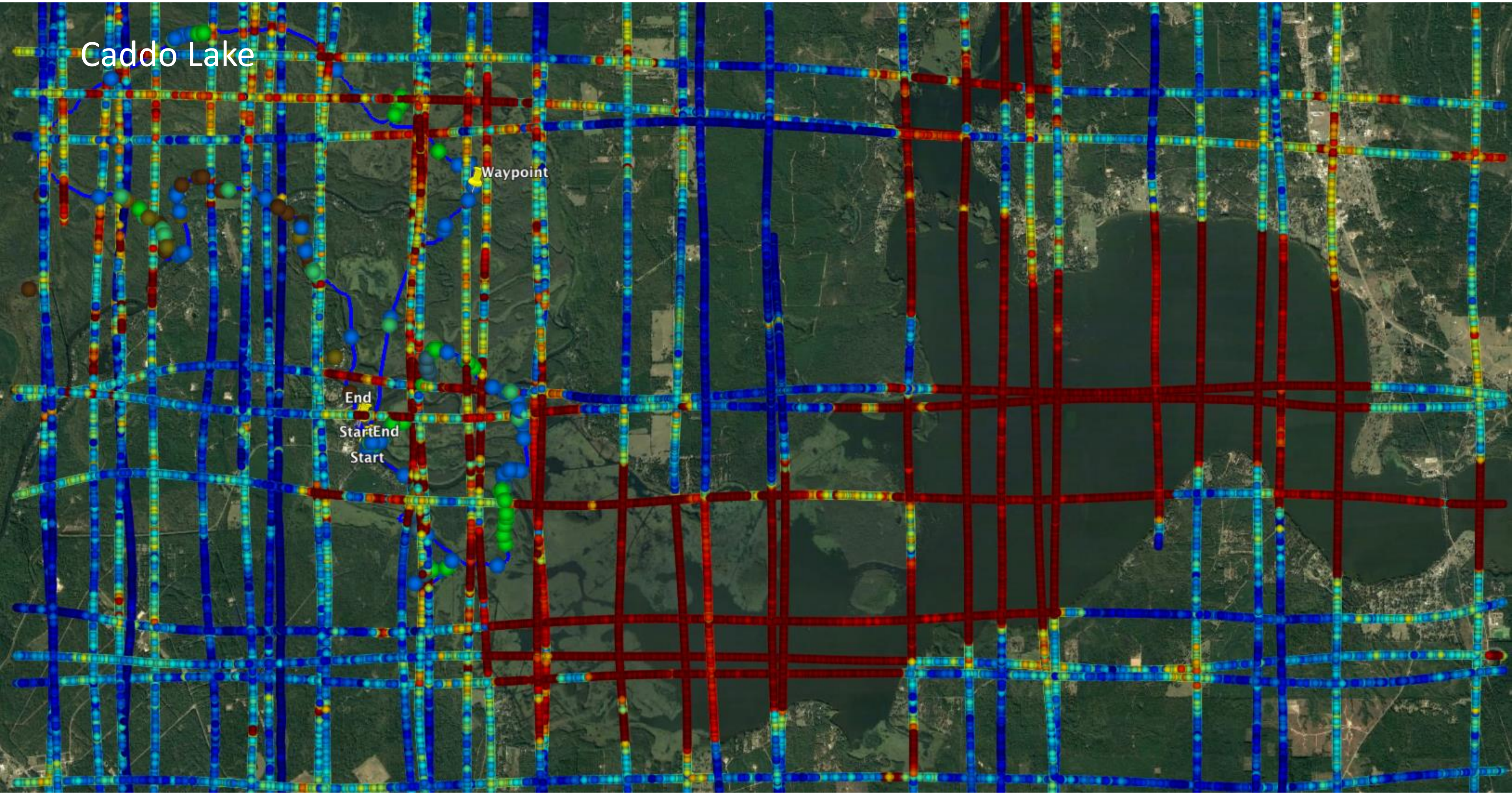
Ground Truth




Sentinel Radar



Preliminary Results



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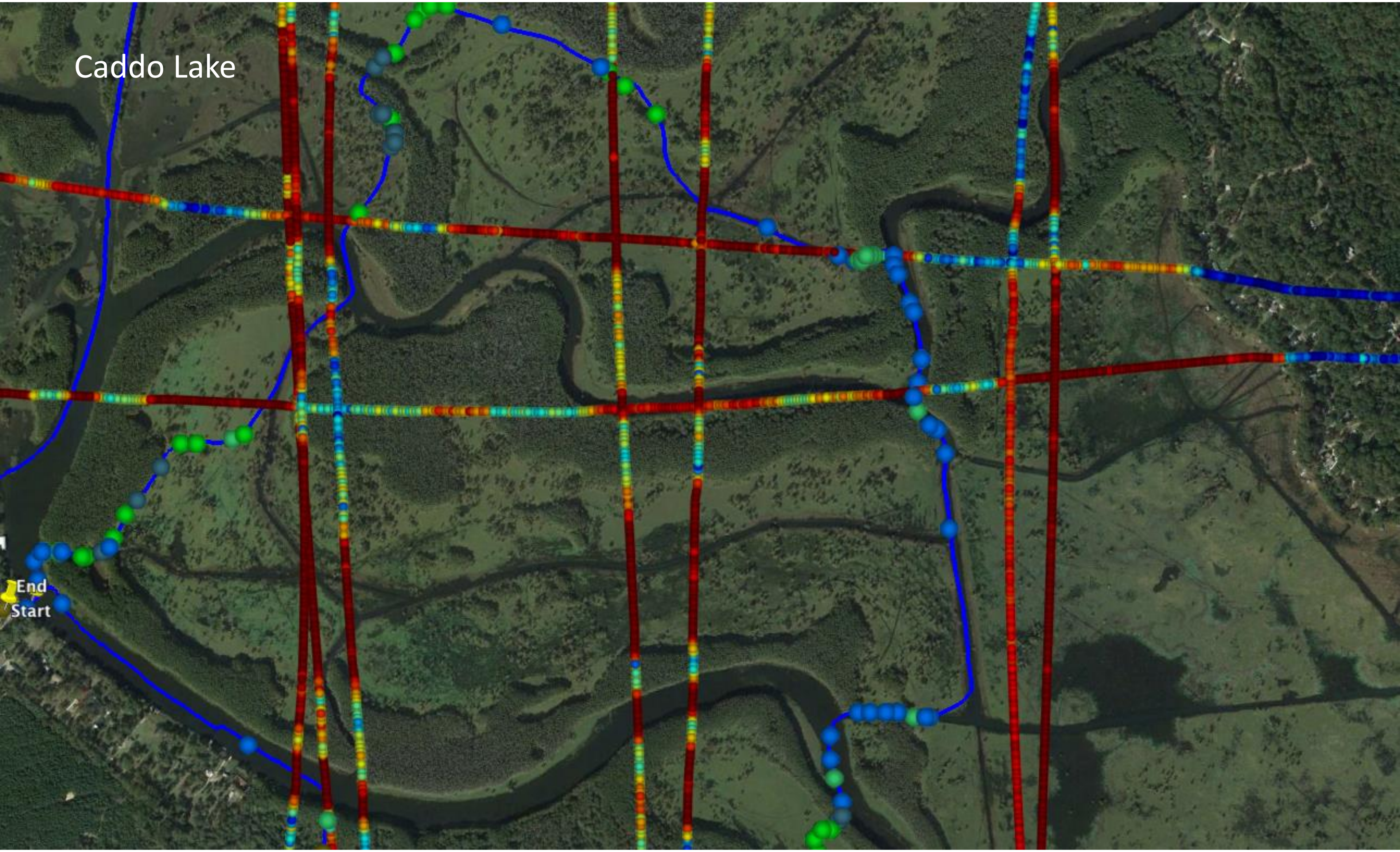

Antenna Gain Measurement

- Aug 21, 2017
- Compare patch array to known geodetic antenna
- Same hardware as flight
- Quickly switch antenna inputs to calibrate LNAs

Next Steps

- Process antenna gain measurements
- Calibrate reflections data for gain and path loss
- Compare to optical and ground truth data
- Assess signal penetration in dense vegetation environment
- Assess ability to measure inundation extent
- Inundation algorithm
- Extrapolate to LEO for global coverage

Summary

- Successfully completed wetlands flight campaign
  - Dual polarization (H/V), GPS L1+L2+L5, 20/40 MHz
  - 1st flight: lakes
  - 2nd flight: CA wetlands
  - 3rd flight: Caddo Lake TX/LA + surroundings

- Goals:
  - Assess GNSS-R for mapping wetland inundation
  - Understand advantages of polarimetric data for wetland science
  - Assess higher bandwidth GNSS signals for wetlands/land
  - Demonstrate M-codeless processing